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Emission Testing of 1974 Pontiac V-8 with Defective Thermal Vacuum Valves

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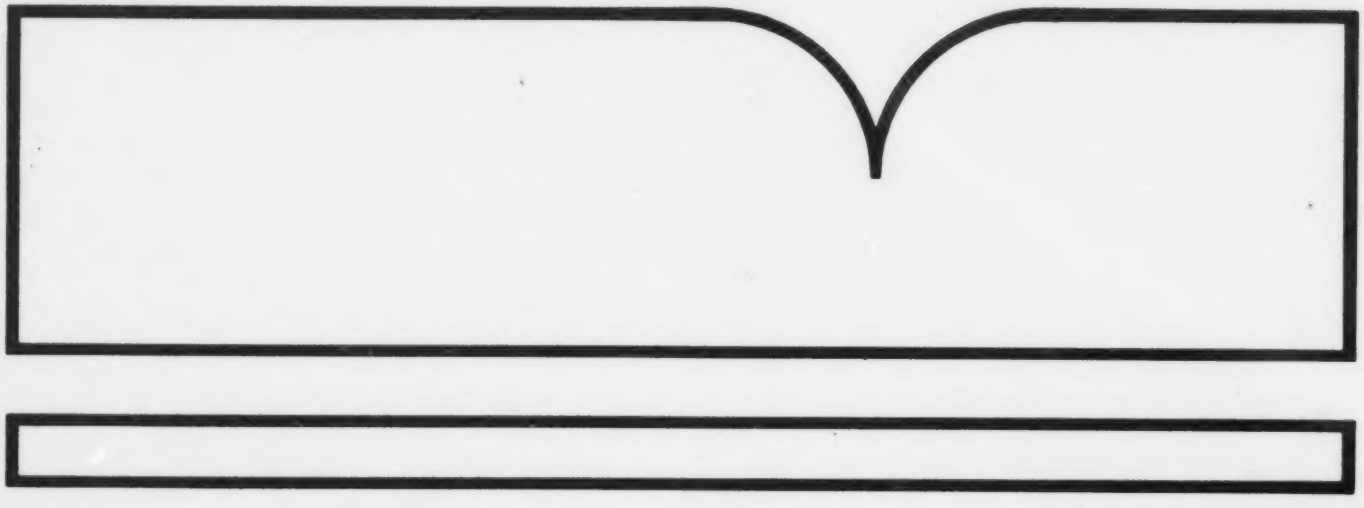

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Technology Assessment and Evaluation Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Environmental Protection Agency

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16. ABSTRACT

The EPA became aware that there were problems with the Thermal Vacuum Valve (TVV) installed in 1974 Pontiac V-8's. To confirm the existence of the problem, functional tests were conducted on TVV's collected from in-service Pontiac vehicles. These tests consisted of applying a controlled vacuum to the valves while raising their temperature in a stepwise fashion andobserving when they actuated. The majority of the valves tested failed to meet their design specifications. In order to quantify the effect of the failed valves on emissions, exhaust emissions tests were conducted with the TVV's installed in a 1974 Pontiac. However, only a limited test program was undertaken. This report describes the exhaust emission test program and presents the data and results. The conclusions drawn from these tests are necessarily of limited applicability. A complete evaluation of the degradation of the emission control system caused by defective TVVs on the 1974 Pontiac V-8's requires a much larger sample of test vehicles than is economically feasible in in-house test projects conducted by EPA.

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Introduction

The EPA recently became aware that there were problems with the Thermal Vacuum Valve (TVV) installed in 1974 Pontiac V-8's. To confirm the existence of the problem, functional tests were conducted on TVV's collected from in-service Pontiac vehicles. These tests consisted of applying a controlled vacuum to the valves while raising their temperature in a stepwise fashion and observing when they actuated. The majority of the valves tested failed to meet their design specifications. The functional tests are described in Appendix A.

Next, in order to quantify the effect of the failed valves on emissions, exhaust emissions tests were conducted with the TVV's installed in a 1974 Pontiac. However due to a heavy test schedule in the Motor Vehicle Emission Laboratory, only a limited test program was undertaken. This report describes the exhaust emission test program and presents the data and results.

The conclusions drawn from these tests are necessarily of limited applicability. A complete evaluation of the degradation of the emission control system caused by defective TVVs on the 1974 Pontiac V-8's requires a much larger sample of test vehicles than is economically feasible in the in-house test projects conducted by EPA. To fully evaluate the system degradation, it is necessary that a more extensive test program be carried out.

The conclusions drawn from this test can be considered to be quantitatively valid only for the specific vehicle used in the test program. Although it is reasonable to extrapolate the results from the test to other 1974 Pontiac engine/powertrains in a directional or qualitative manner, tests of the TVVs on other such vehicles would be required to reliably quantify the results on other engine/powertrain combinations. However, because of the magnitude and consistency of the directional trend for NOx emissions found in this test, one can reasonably conclude that a failed TVV can cause NOx increases substantial enough to create a high probability that the vehicle would fail to meet the applicable NOx standard.

System Description

The 1974 Pontiac V-8 uses an emission control system that employs a transmission controlled spark (TCS) to control distributor advance and exhaust gas recirculation (EGR). Engine vacuum signals supplied at the carburetor are used to control the EGR valve and distributor advance. The sending of these signals is controlled in part by the TVV.

The valve, Figure 1, is a dual function thermal switch. It is activated by intake manifold air temperature. The valve allows a vacuum

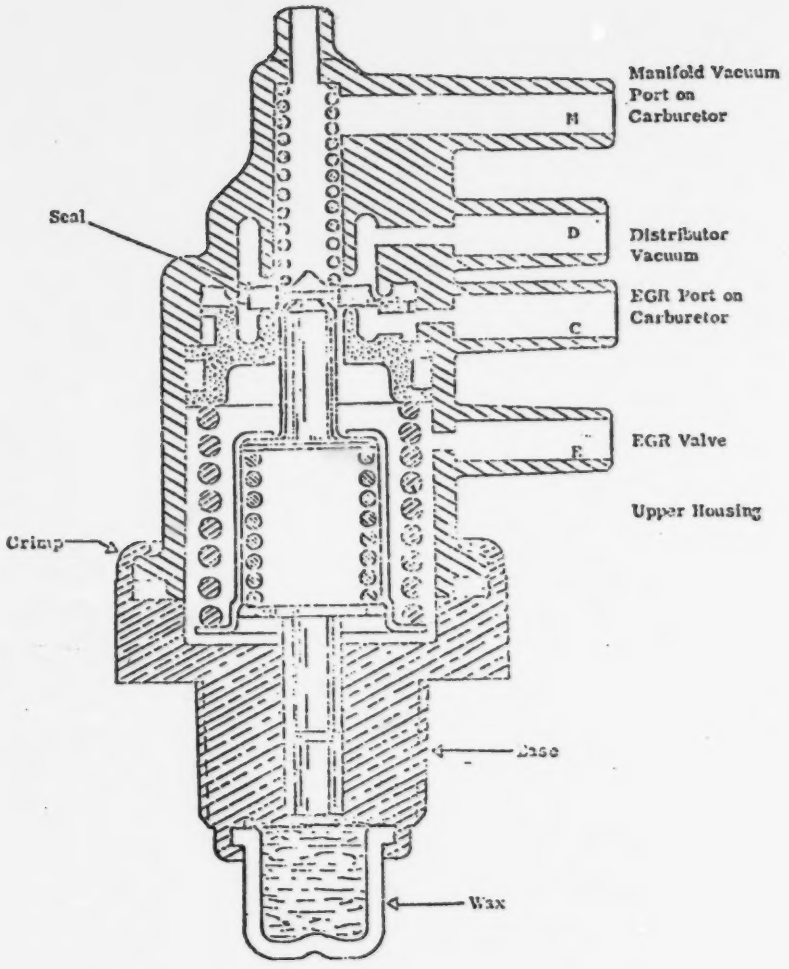


Figure 1 1974 Pontiac V-8 Thermal Vacuum Valve (Dole)

Specifications: Harrison	Dole
EGR starts to open 57 $\pm$ 5°F between normally closed port C to E	Calibrated EGR on and distributor off at 62°F $\pm$ 3°F
Distributor closed 62°F $\pm$ 5°F between normally open port M to D	EGR on $<$ 57°F EGR off $>$ 67°F
	Distributor on $<$ 57°F Distributor off $>$ 67°F

Note: Dole and Harrison valves are functionally identical.

signal to be sent to the EGR valve at temperatures above 62°F. It simultaneously shuts off the direct vacuum signal to the distributor. The typical installation schematic is shown in Figure 2.

The test vehicle was a 1974 Pontiac LeMans Sport (the vehicle is described in detail on the following page). To ensure that the test results would be representative, the vehicle was thoroughly checked out and tuned up prior to testing. Major items checked were cylinder compression, dwell, timing, idle rpm, idle CO, exhaust system, cooling and fuel systems. Air, oil, and fuel filters were replaced. New sparkplugs, points, condensor and PCV valve were installed and the oil was changed. The EGR valve and the carburetor on the vehicle were malfunctioning, and were replaced with new units. The vehicle was then tuned to manufacturer's specifications.

Test Procedure

Exhaust emission tests were conducted according to the 1975 Federal Test Procedure ('75 FTP), described in the Federal Register of November 15, 1972 except that no evaporative emissions tests were conducted. All testing was conducted using an inertia weight of 4500 pounds (2041 kg) with a road load setting of 14.0 horsepower (10.4 kw) at 50 miles per hour (80.5 km/hr).

Two baseline tests were run with the vehicle adjusted to manufacturer's specifications. After completion of the baseline tests, malfunctioning TVVs were installed on the test vehicle. Two tests were run on the test vehicle with each TVV. The TVVs tested were selected to be representative of the types of failures noted during the previous bench checks. The valves tested were:

TVV Number	Fault
32	New valve, no malfunctions
6	No EGR, no vacuum advance shutoff
14	Late EGR (170°F), no vacuum advance shutoff
1	No EGR, late vacuum advance shutoff (150°F)
2	No EGR, late vacuum advance shutoff (150°F)

Test Results

Exhaust emissions data, summarized below, showed that the defective TVVs caused the NOx emissions from the test car to exceed the standard for the 1974 model year. Results are expressed as '74 FTP emissions,

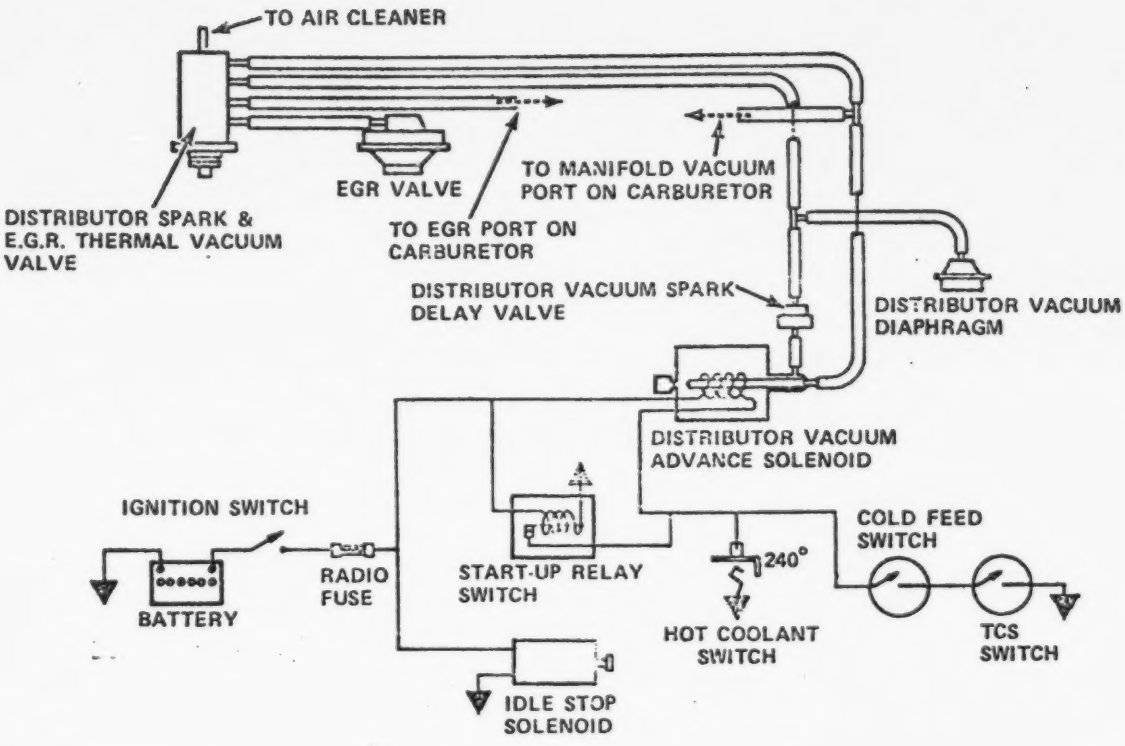


Figure 2 Typical Emission Control System for 1974 Pontiac V-8

Typical Specifications:

EGR Valve 2" Hg starts to open
5" Hg fully open
.7 to .8 lb./min exhaust flow

Distributor Advance 7" Hg 0° Advance
14" Hg 20° Advance

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1974 Pontiac LeMans
Emission control system - EGR, Transmission Controlled Spark (TCS)

Engine

type	4 stroke, Otto cycle, OHV, V-8
bore x stroke	3.875 x 3.746 in.
displacement	350 cu. in.
compression ratio	7.6:1
maximum power @ rpm	
fuel metering	single 2 barrel carburetor
fuel requirement	regular unleaded (tested with indolene HO, unleaded)

Drive Train

transmission type	3 speed automatic
final drive ratio	2.73:1

Chassis

type	body-on-frame, front engine, rear drive
tire size	HR 78 x 14
curb weight	4140 pounds
inertia weight	4500 pounds
passenger capacity	5

Emission Control System

basic type	EGR, transmission controlled spark advance (TCS)
durability accumulated on system	27,850 miles

the procedure used to certify the vehicle. This test is a cold start LA-4 driving cycle and consists of the first two test phases of the '75 FTP (Bag 1 and Bag 2). Detailed results appear at the end of this report.

'74 FTP Mass Emissions
grams per mile
(grams per kilometre)
average of two tests

TVV No.	HC	CO	CO2	NOx	Fuel Economy (Fuel Consumption)
32	2.16 (1.34)	21.84 (13.57)	838 (517)	1.51 (.94)	10.1 miles/gal. (23.2 litres/100km)
6	2.89 (1.80)	17.97 (11.17)	749 (465)	4.45 (2.77)	11.3 miles/gal. (20.9 litres/100km)
14	3.10 (1.92)	18.62 (11.57)	719 (447)	4.56 (2.83)	11.7 miles/gal. (20.2 litres/100km)
1	2.50 (1.55)	21.34 (13.26)	796 (495)	4.19 (2.60)	10.6 miles/gal. (22.2 litres/100km)
2	2.47 (1.54)	19.71 (12.25)	758 (471)	3.99 (2.48)	11.1 miles/gal. (21.1 litres/100km)
74 Federal Standards	3.4	39.0		3.0	

Expressed as a percentage change from baseline, the results showed:

'74 FTP Mass Emissions
Percent change from Baseline*

TVV no.	HC	CO	CO2	NOx	Fuel Economy
6	34%	-18%*	-11%*	195%	12%
14	44%	-15%*	-14%*	202%	16%
1	16%	- 2%*	- 5%*	178%	5%
2	14%	-10%*	-10%*	164%	10%

* A negative sign indicates a decrease in emissions/fuel economy.

Thus, although the defective valves improved CO emissions and fuel economy, they increased HC and NOx emissions. The increase in NOx emissions was sufficient to cause the vehicle to fail to meet the 1974 emission standards. While there was an improvement in fuel economy, comparative certification data for the 1975 and 1976 equivalent vehicle showed fuel economies of 10.8 and 12.9 miles per gallon respectively, even though these cars met more stringent exhaust emissions standards.

For one test on valves number 2 and 14 a thermocouple was attached to the valve body. The time/temperature trace showed a gradual rise from ambient (70^{o}F) conditions to operating temperatures (150^{o}F); at between 50% and 80% of the '74 FTP driving cycle the temperature would stabilize at 150^{o}F. Since this is probably representative of the warmup cycle each valve would experience, a comparison of the valve faults and emission test results leads to several additional conclusions about the valves' effects on emissions. The change in HC and CO emissions was largely the result of late vacuum shutoff. The change in NOx emissions is largely the result of lack of EGR.

Conclusions

Thermal vacuum valves which failed to meet specifications in the functional tests caused high NOx emissions (in excess of the 1974 standard) when installed in the test vehicle, a 1974 Pontiac 350.

Installation of the defective valves also caused hydrocarbon emissions to increase significantly, carbon monoxide emissions to decrease slightly and fuel economy to improve slightly.

'75 FTP Mass Emissions
grams per mile

Valve Number	Test Number	Bag 1 Cold Transient HC	CO	CO_2	NOx	Fuel Eco. MPG	Bag 2 Hot Stabilized HC	CO	CO_2	NOx	Fuel Eco. MPG	Bag 3 Hot Transient HC	CO	CO_2	NOx	Fuel Eco. MPG
32	77-1683	2.94	36.72	859	1.78	9.6	1.83	10.37	788	1.48	11.0	2.25	14.61	663	1.93	12.8
32	77-1727	2.45	31.33	866	1.67	9.6	1.47	11.17	822	1.16	10.5	1.75	15.78	710	1.49	12.0
6	77-1728	3.06	29.35	758	4.95	10.9	2.78	7.34	725	3.58	11.9	2.61	8.46	650	5.70	13.2
6	77-1800	3.06	29.01	784	5.46	10.6	2.68	8.03	732	3.92	11.8	2.48	7.90	660	6.16	13.1
14	77-1804	3.29	27.23	722	5.16	11.4	3.04	9.02	715	3.49	12.0	3.07	13.03	620	4.26	13.6
14	77-2070	3.35	31.02	722	5.73	11.4	2.74	8.91	718	3.99	12.0	2.64	10.00	620	6.03	13.8
1	77-1801	3.15	28.22	725	4.78	11.4	1.70	12.80	794	2.16	10.8	1.93	12.27	622	3.64	12.9
1	77-2071	3.57	36.19	802	6.34	10.2	1.71	9.90	859	3.69	10.1	1.82	11.94	736	5.78	11.7
2	77-1985	3.15	29.97	722	5.15	11.4	1.85	11.21	775	2.50	11.1	1.97	13.90	665	4.00	12.8
2	77-2070	3.31	29.18	739	5.82	11.2	1.70	10.09	793	2.72	10.9	1.86	11.36	685	4.48	12.5

'75 FTP Composite Mass Emissions
grams per mile

Valve Number	Test Number	HC	CO	CO_2	NOx	Fuel Eco. MPG
32	77-1683	2.18	16.95	769	1.67	11.1
32	77-1727	1.75	16.58	800	1.35	10.7
6	77-1728	2.79	12.17	711	4.44	12.0
6	77-1800	2.71	12.31	723	4.85	11.8
14	77-1804	3.10	13.86	691	4.04	12.3
14	77-2070	2.84	13.76	692	4.90	12.3
1	77-1801	2.06	15.83	744	3.10	11.4
1	77-2071	2.60	15.87	813	4.80	10.5
2	77-1985	2.12	15.81	734	3.45	11.6
2	77-2140	2.08	14.37	753	3.84	11.3

Appendix A

Functional Tests of Pontiac Thermal Vacuum Valves

Twenty-eight Thermal Vacuum Valves (TVV's) removed from in-use Pontiac V-8 automobiles were tested at the EPA Motor Vehicle Emission Laboratory to determine whether the valves actuated as they are designed to do.

The tests consisted of applying a controlled vacuum to the valve at the proper port, while raising the actuation temperature in a stepwise fashion and observing when the valve actuated by measuring the vacuum at another port. For instance, referring to Figure A-1: vacuum applied to port 'M' was observed with a vacuum gage at port 'D'. Likewise, a vacuum applied at port 'C' was observed at port 'E'. The valves were also checked for leaks.

Vacuum test results are depicted in Figure A-2 in which valve actuation temperature for each function is shown for each valve. Of the twenty-eight valves tested (number 10 was broken and not tested), twenty-five did not provide the required vacuum signal at the design temperature. Principal faults were late cutoff of distributor manifold vacuum, late EGR actuation and early EGR actuation.

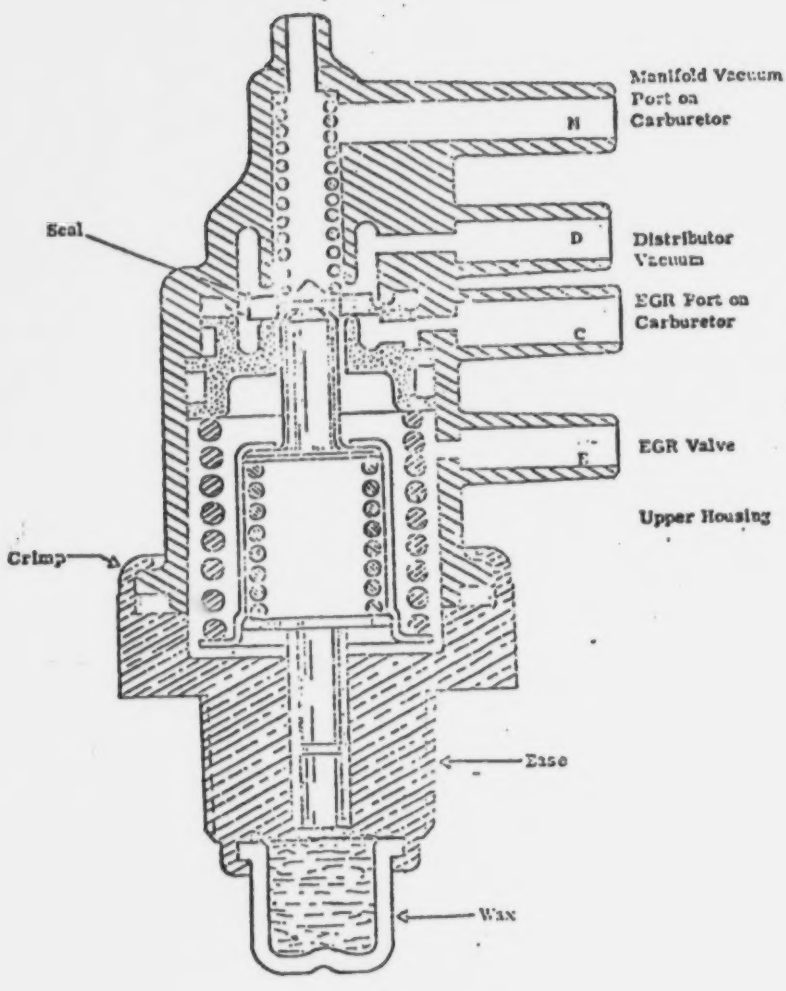
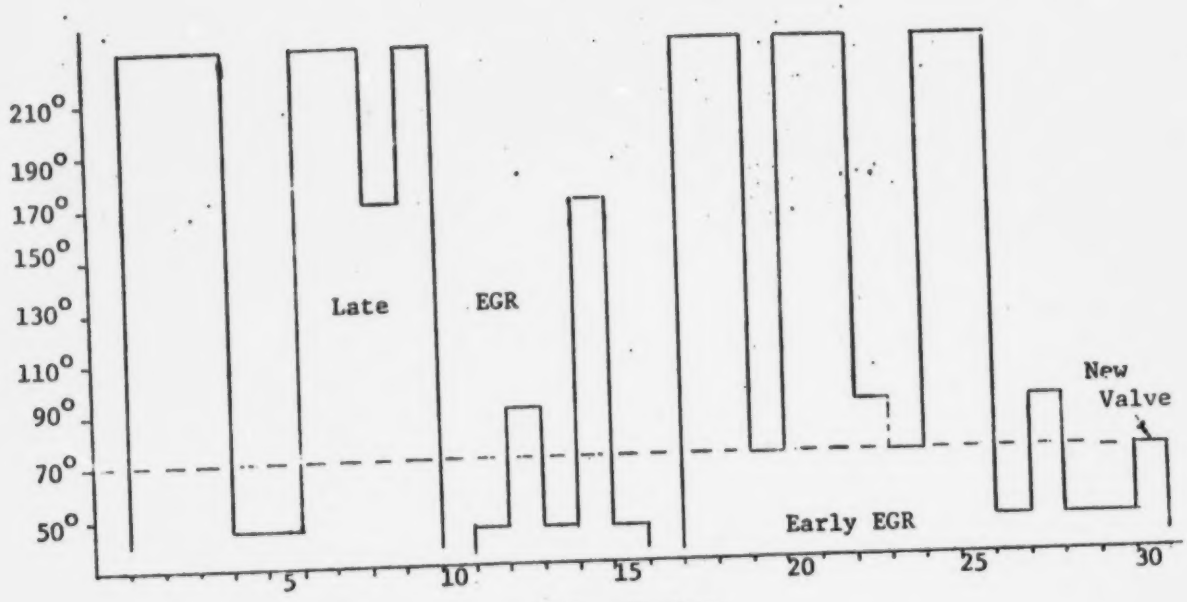


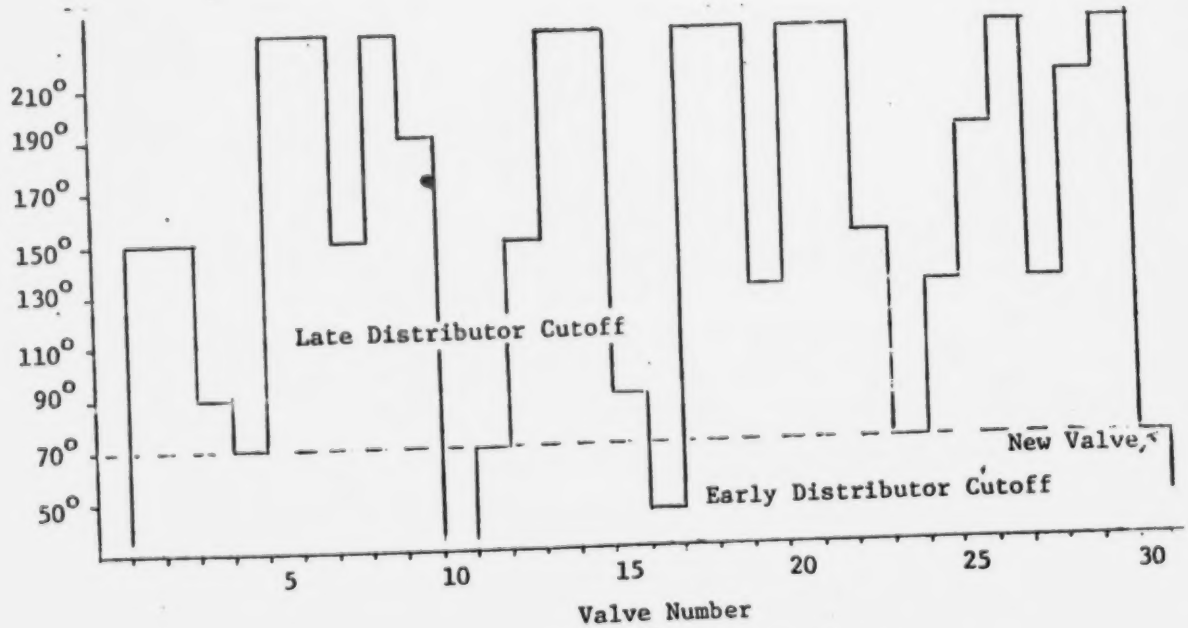
Figure A-1 1974 Pontiac V-8 Thermal Vacuum Valve (Dole)

Specifications: Harrison	Dole
EGR starts to open 57 $\pm$ 5°F between normally closed port C to E	Calibrated EGR on and distributor off at 62°F $\pm$ 3°F
Distributor closed 62°F $\pm$ 5°F between normally open port M to D	EGR on < 57°F EGR off > 67°F
	Distributor on < 57°F Distributor off > 67°F

Note: Dole and Harrison valves are functionally identical.



EGR Valve Actuation



Direct Distributor Vacuum Advance

Figure A-2 Summary of Functional Test Results